Innovation and Entrepreneurship: Merging Engineering and Business

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Abstract- **The ability for engineers and those in business fields to understand perspectives beyond their own expertise and to work together productively is critical to the success of an organization. To address this educational need, we are developing a certificate program that focuses on bringing business and engineering students together in a product development and business environment. The goal is to develop a valuable long-term business and engineering educational partnership at Texas Tech University. Students in this course, presented by the author at Iowa State University, were from Management, Management Information Systems, and Marketing, as well as Electrical, Mechanical, and Industrial Engineering majors. Teams, each consisting of two business and two engineering students, worked on products in a wide variety of areas: rehabilitation devices, process improvements, equipment for the aging, medical monitoring devices, and exercise equipment. Results were encouraging and will provide a basis for future efforts as we integrate refined versions of this course into Texas Tech University's certificate program. We feel the benefits for the student result from their using their expertise in a multidisciplinary environment that allows them to understand the contributions of other backgrounds to a successful technical/ entrepreneurial collaboration.**

Index Terms- product innovation, business perspective, engineering perspective

INTRODUCTION

Engineers today must not only understand the physical design characteristics of a product or system, but also the business perspective that has traditionally been the territory of management. The capacity for engineers and those in business fields to understand perspectives beyond their own, and work together productively, will be critical to the success of today's organizations. As today's (and tomorrow's) engineers move through their careers, they must have the skill to respond as their environment changes. That is, an engineer must become an adaptable and self-sufficient business unit, regardless of job, management, or location- an entrepreneur. Engineering education should foster this vision of individual entrepreneurship and entrepreneurial thinking.

Traditional engineering knowledge and skills have focused on product and service design, manufacturing, and technical support. We expand beyond these by focusing on entrepreneurial thinking- creating technology-based opportunities and meeting the challenges of identifying and developing technology into new or improved products and services. A business school based entrepreneurial program might focus on topics such as designing operational models, resource acquisition and leveraging, and financial risk management. In contrast, an engineering-based course would focus on innovation, intelligent risk taking, technology planning and development processes, requirement assessments, and intellectual property. How can we best expose our students, our future workforce, to these diverse perspectives? Several authors discuss courses developed with a focus on the value of entrepreneurial engineering (and so entrepreneurial thinking) and the use of an innovation based philosophy in their successes [1]-[2]. We feel that by blending interdisciplinary course work with team projects, an environment is created for the students to more effectively gain experience in entrepreneurial thinking.

To better address the need for interdisciplinary understanding and communication, we have developed a certificate program at Texas Tech University. The program will include a series of courses that focus on bringing business and engineering students together in a product, process, and business development environment. This program will be part of an effort to develop a valuable long-term business and engineering educational partnership at Texas Tech. In this paper, we will focus the development of a course offered at Iowa State University by the author, which will now serve as the basis for the first Texas Tech University engineering offering.

COURSE DESIGN

The course was developed with a diverse audience in mind. Its focus was on developing better understanding of the roles played both the engineering and the business side of product development. Majors represented in the first offering of the engineering pilot course were from Management, Management Information Systems, Marketing, as well as Electrical, Mechanical, and Industrial Engineering. The class provides students with a real-world perspective on the product innovation and realization process. Each lecture introduced scenarios (mini-cases) developed from journal articles taken from various disciplines. Discussions explored design, creativity stimulation, decision analysis methods, market analysis, profitability, and design aesthetics. The first

lecture dealt with the product design process, highlighting the roles of both business and design in achieving a successful result. Seminars given by successful entrepreneurs from different industries were focused on developing new technologies and new products. We also incorporated sessions for team-based brainstorming, in which the teams identified three to five top product or process improvement ideas for further research. Lectures alternated between business and engineering topics, with time devoted in class for application of the concepts presented. Several lectures were devoted to the teams working on course deliverables, with others focused on intellectual property, patents, and market research.

The most challenging (and critical) features of the course were in selecting teams and in identifying product ideas. Teams, consisting of two business and two engineering students, were formed by having the students make a three-minute presentation in class to sell both their skills and themselves as a potentially valuable asset. Students then contacted students to form the teams. Products for both projects and mini-cases were chosen from a wide variety of areas such as rehabilitation devices, equipment for the aging, medical monitoring devices, and process improvements in local companies. Teams were expected to develop a feasible product or process idea that was both novel and marketable, but not necessarily create a working prototype. Teams were responsible for conducting a preliminary market research, developing a financial analysis, as well as developing plans for producing, marketing, distributing, and selling their product. A slight variation on these course requirements were required if the project involved a process innovation.

SELECTED COURSE TOPICS

Tools and techniques were presented for exploring course concepts. Their use in answering relevant questions during the product development process was highlighted. The material was presented in an approach that we felt would be understandable and useful for students from both of the main audiences.

I. Engineering Topics

Three tools made up the engineering foundation for the course: quality functional deployment (QFD), Value Engineering (VE), and TRIZ. These tools addressed understanding the requirements for the product, deciding on the functions and specifics of the product, and how to produce usable ideas.

- *Quality Functional Deployment (QFD):* QFD is a technique for insuring a product or process meets customer needs. The team first identified and captured customer requirements for their idea, then translated them into technical specifications to select product characteristics. A series of interrelated matrices and tables were used to carry out the translation. Students were exposed to the most widely used QFD model for product development- a series of four linked matrices: product specification, component specification, manufacturing process specification, and production rules specification. In this sequence of matrices, each uses information from a preceding matrix as its starting point. These interrelated tables and matrices form a House of Quality [3]. QFD has proven to be a useful support tool that helps multidisciplinary teams manage the large quantities of information necessary to make today's product development decisions. This tool helped students answer questions such as: What are the qualities the customer wants? What functions must the product supply? What functions must we use to provide the product or service? Based on the resources available, how can we best provide what our customer wishes? How can we do this given the characteristics of our competitors' products?
- *TRIZ:* Innovation is an important quality for those involved with product or process improvements. Many methods can be used to encourage creativity. Techniques, such as brainstorming and morphological analysis, produce creative solutions by combining expertise that exists within a team. These approaches depend on individual experiences and knowledge and teams may, to find a solution, resort to oversimplifying the situation surrounding a complex problem. The TRIZ (in Russian *teorija rezhenija izobretatelskih zadach* which means the "theory of inventive problem solving") process uses universal principles of invention (developed from analysis of patents) to provide a framework for developing innovations. The technique translates a specific problem into an abstract problem, and then uses a generic design guideline (pattern) relevant to the problem to find a solution. The TRIZ process is systematic, replacing the trial-and-error methods of many traditional creativity tools [4]-[5]. The TRIZ tool helped the students answer questions such as: How can we improve an existing system? How can we develop ideas for a new product? What are the main functions of the system? What parts are needed to produce the required functions?
- *Value Engineering:* Value Engineering (VE) analyzes products and services. It integrates necessary functions and essential characteristics of a product to create maximum value, as defined by the user. The goal of VE is to increase value by lowering cost, increasing functionality, or by some combination of these two. VE depends on the designer understanding the user or buyer's definition of value. Function Analysis System Technique (FAST) diagrams are used to prioritize the objectives and functions of the product. Alternatives are then evaluated to find those that would return the most value based on predetermined criteria. FAST allows people with different technical backgrounds to communicate effectively and resolve issues in situations that require multidisciplinary considerations [6]. This tool helped students answer questions such as: What will be the value of avoiding problems during product development? How can we develop better project definition during the conceptual stage? How can we develop more accurate estimates for the parts and functions of our product and their related costs?

II. Business Topics

Three business concepts made up the foundation for this portion of the course: marketing, cost-benefit analysis, and financial planning. While these are not tools in the sense of the primary engineering concepts, they provided an approach to understanding major features from the business side of the product design process.

- *Financial Analysis and Planning.* The teams developed a financial analysis and plan for producing, marketing, distributing, and selling their product. To do this successfully, they had to agree on a model for developing their product and business. Cost estimation and the basics of developing financial statements were taught using case studies that explained different entrepreneurial business models. This topic help us focus the students on answering questions such as: How do they create a startup? How many people will be involved? How will people be paid until we reach profitability? How much will it cost to develop and manufacture the product? How will it be manufactured? How will it be distributed? How can we best market the product? What should be our selling price and why?
- *Marketing Plan.* We focused on developing a marketing plan that emphasized developing a product description, identifying the need for their product, carry out a competitive analysis of existing products, and developing a strategy for getting funding for the product development. Information from this topic could be used by the students to answer questions such as: Is our idea practical? What information should we develop to attract outside investors? What information do we need to develop a base for more detailed planning? How should we track our progress after starting the business? When should we start selling our new product or service? Should we consider selling outside our current target market?
- *Cost-benefit analysis.* A cost-benefit analysis (CBA) finds, quantifies, and adds all the positive factors (the benefits) relevant to a decision. Then it identifies and subtracts all the negatives (the costs). The difference between the two suggests whether the planned action is advisable. (Note that this business topic is similar to the engineer's value analysis.) The difficulty in doing a CBA well is making sure all the costs and all the benefits are included, and that a technique to quantify them properly is used. The decision about whether to include intangible costs or benefits and if so, how they can best be incorporated, adds more complexity when using this concept. This topic allowed the students to answer questions such as: What are the tradeoffs between manufacturing our product in-house and outsourcing? What are the tradeoffs between using steel or plastic in our product? What are the tradeoffs among getting venture capital, bank loan, or small business grant to fund our idea- or should we use all of them?

Creativity and innovation were stressed throughout the course as being essential to entrepreneurial thinking and product development. Formal methods of concept development, idea generation, and evaluation were presented such as TRIZ, morphological analysis, brainstorming, and decision trees, as well as the fundamentals of engineering design and business previously discussed.

Our expectation was that students would begin to understand basic concepts from the other disciplines and develop the ability to communicate effectively between the fields. That is, the business students took lead responsibility in completing the financial analysis and marketing plans, but the engineering students developed enough of an understanding to evaluate the work and suggest improvements. The same was true of the business students for the engineering related deliverables such as product functionality, specifications, and design. This approach mimics what they will experience in the business world – team members working together to leverage complementary strengths to complete a project.

RESULTS AND DISCUSSION

Entrepreneurial thinking is a skill of growing importance, and will have a significant impact on the engineering profession as a complement to traditional engineering functions. Undergraduate and graduate programs must improve the quality and rate of development of engineers that can think entrepreneurially. Entrepreneurial engineering education recognizes the specific role engineers can play in creating business opportunities and by focusing on the evolving needs of engineers working in today's business environment.

Student responses to this approach were positive. A survey was used to obtain student perceptions of the course. An interesting (and hoped for) finding was an increase in understanding the role others play in the product cycle from that found at the beginning of the course, by both engineers and business majors. The students felt the approach used allowed them to better appreciate the roles and contributions of other fields. They also found the course to be both challenging and time intensive, because of the large amount of team interaction needed for success. We provided a set of clear expectations and an explanation of the time commitment needed for mastering the material (and for producing a feasible idea) on the first day of the course. Students felt this clear-cut schedule of deliverables, and their requirements, was a useful aid for team time management. As the course is revised for use at Texas Tech University, even greater attention will be paid to developing suitable expectations for both faculty and student.

These first results were encouraging and provide a basis for future efforts as we incorporate refined versions of this course into the Texas Tech certificate program. Our next steps include putting even more engineering and business students together in the classroom, and ensuring that—in addition to making clear the time and deliverable expectations—we will also focus on teaching the interpersonal/ flexibility skills needed for cross-disciplinary study. We feel the benefits for the student result from their applying their expertise in a multidisciplinary environment, as well as providing opportunities to develop an

understanding of the contributions of others to successful technical/ entrepreneurial collaborations.

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